Rail Accident Investigation Branch

Rail Accident Report

Class investigation into factors affecting safety-critical human performance in signalling operations on the national network

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This investigation was carried out in accordance with:

- the Railway Safety Directive 2004/49/EC
- the Railways and Transport Safety Act 2003
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Preface

The purpose of a Rail Accident Investigation Branch (RAIB) investigation is to improve railway safety by preventing future railway accidents or by mitigating their consequences. It is not the purpose of such an investigation to establish blame or liability. Accordingly, it is inappropriate that RAIB reports should be used to assign fault or blame, or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose.

RAIB's findings are based on its own evaluation of the evidence that was available at the time of the investigation and are intended to explain what happened, and why, in a fair and unbiased manner.

Where RAIB has described a factor as being linked to cause and the term is unqualified, this means that RAIB has satisfied itself that the evidence supports both the presence of the factor and its direct relevance to the causation of the accident or incident that is being investigated. However, where RAIB is less confident about the existence of a factor, or its role in the causation of the accident or incident, RAIB will qualify its findings by use of words such as 'probable' or 'possible', as appropriate. Where there is more than one potential explanation RAIB may describe one factor as being 'more' or 'less' likely than the other.

In some cases factors are described as 'underlying'. Such factors are also relevant to the causation of the accident or incident but are associated with the underlying management arrangements or organisational issues (such as working culture). Where necessary, words such as 'probable' or 'possible' can also be used to qualify 'underlying factor'.

Use of the word 'probable' means that, although it is considered highly likely that the factor applied, some small element of uncertainty remains. Use of the word 'possible' means that, although there is some evidence that supports this factor, there remains a more significant degree of uncertainty.

An 'observation' is a safety issue discovered as part of the investigation that is not considered to be causal or underlying to the accident or incident being investigated, but does deserve scrutiny because of a perceived potential for safety learning.

The above terms are intended to assist readers' interpretation of the report, and to provide suitable explanations where uncertainty remains. The report should therefore be interpreted as the view of RAIB, expressed with the sole purpose of improving railway safety.

Any information about casualties is based on figures provided to RAIB from various sources. Considerations of personal privacy may mean that not all of the actual effects of the event are recorded in the report. RAIB recognises that sudden unexpected events can have both short- and long-term consequences for the physical and/or mental health of people who were involved, both directly and indirectly, in what happened.

RAIB's investigation (including its scope, methods, conclusions and recommendations) is independent of any inquest or fatal accident inquiry, and all other investigations, including those carried out by the safety authority, police or railway industry.

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Class investigation into factors affecting safety-critical human performance in signalling operations on the national network

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Summary

Since it became operational in 2005, RAIB has investigated numerous incidents in which signaller decision-making has been pivotal, and where the safety of the railway system was heavily dependent on those decisions (that is, scenarios in which there were no, or limited, engineered safeguards). Under its remit, RAIB also collected industry data on several similar incidents over a five-year period which again highlighted the vulnerable nature of such decision-making. In the light of these incidents, we undertook a class investigation into what affects those decisions, recognising that they may be influenced by a variety of systemic factors. Although this investigation is about what can go wrong, it must be recognised that front-line decisions also contribute much more widely to the safe operation of the railway on a daily basis.

The investigation examined five categories of incident:

- user worked crossing irregularities
- line blockage irregularities
- users trapped at CCTV level crossings
- irregularities involving level crossings on local control
- other operational irregularities.

The investigation identified several common factors influencing the actions of signallers across these scenarios, associated with:

- signaller workload
- user-centred design
- competence management
- experiential knowledge
- organisational structure.

The report also observes that Network Rail’s incident investigations do not always fully exploit the opportunities to learn from these incidents.

As a result, RAIB has made six recommendations to Network Rail, addressing each of the five areas listed above as well as the observation on learning from incident investigations. There is also a learning point for incident investigators relating to the identification of systemic causal factors.

Introduction

Definitions

1 Metric units are used in this report, except when it is normal railway practice to give speeds and locations in imperial units. Where appropriate the equivalent metric value is also given.

2 The report contains abbreviations that are explained in Appendix A. Sources of evidence used in the investigation are listed in Appendix B, while a bibliography of key reference sources can be found in Appendix C.

Acknowledgements

3 We are grateful to Dr David Golightly of Newcastle University for his support in carrying out the field work and associated analysis for this investigation.

Context

Background to the class investigation

4 Since it became operational in 2005, RAIB has investigated numerous incidents in which the decisions of front-line workers have been pivotal, and where the safety of the railway system has been heavily dependent on those decisions (that is, scenarios in which there were no, or limited, engineered safeguards). Moreover, RAIB has collected industry investigation reports on several similar incidents which, although not reaching the criteria for a full RAIB investigation, highlight the vulnerable nature of such decision-making. In the light of these incidents, we undertook a class investigation into the factors affecting those decisions.

5 Fundamental to this investigation is the recognition that such decisions are never taken in isolation, but may be influenced by a variety of factors associated with the person, the task, the equipment, the environment or the organisation. The investigation also acknowledges that front-line decisions, while they are occasionally causal in incidents or accidents, also contribute much more widely to safe operations on a daily basis; generic values of human reliability for typical signalling tasks exceed 99%, but error probabilities can be multiplied many times by external factors.[1] Therefore, it is important to understand how such decisions are taken in the context of the factors that influence them. The purpose of the class investigation is to identify these factors and to determine what actions may be appropriate to address them in order to optimise decision-making.

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[1] ‘Railway Action Reliability Assessment user manual: A technique for the quantification of human error in the rail industry’, June 2012. RSSB.

6 Many of the incidents under consideration involve decisions made by signallers. This is perhaps unsurprising given the central role signallers play in several aspects of running the railway, and the fact that in many of these, their decisions and actions are, by design, the main barrier to preventing a safety incident. This investigation has examined incidents in five categories:

- user worked crossing[2] (UWC) irregularities: in which a signaller has granted permission for a member of the public to cross the railway while a train is approaching
- line blockage irregularities: in which a signaller has blocked a section of the line to protect track workers, either with a train already in that section, or has subsequently signalled a train through that section (note that for the purposes of this report, similar irregularities involving possessions of the line are included, since they depend on equivalent decisions and actions by signallers)
- users trapped at CCTV level crossings: in which a signaller has cleared the signals for a train to approach a full barrier level crossing while a user (typically a pedestrian) is trapped inside the barriers
- irregularities involving level crossings on local control: in which a train has passed over a level crossing with the barriers raised, while maintenance work was taking place on that crossing necessitating it being controlled locally by a level crossing attendant
- operational irregularities: arising from any kind of train movement under normal, abnormal or degraded signalling operations, which may include two trains in the same signal section, or one train being routed towards another, or an otherwise dangerous wrong routeing.

7 At the time of writing, Network Rail owns and operates about 500 signal boxes and signalling centres across the Great Britain national network. These can be broadly divided into three different types of signaller work environment: lever frame signal boxes (figure 1), signalling centres with control panels (figure 2) and signalling centres with computer workstations (figure 3). Although exact figures are difficult to determine, because many locations contain a mix of these technologies, about 60% of this total are lever frame signal boxes, just under one-third use primarily control panels, while the remainder use primarily computer workstations. Despite the relatively small number of signalling centres with computer workstations, each centre typically contains multiple workstations (an average of about five per centre, with some of the larger centres hosting up to 15 workstations) and each workstation controls a much larger area than an individual lever frame box. Across all of these locations, Network Rail employs around 5200 signalling staff. Network Rail freely cooperated with the investigation.

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[2] A type of level crossing where the barriers or gates are opened and closed by the user. Many such crossings have a telephone for some users to request permission to cross from the signaller (see paragraph 9); these are referred to in the rail industry as UWC(T). Since UWCs without telephones require no interaction with the signaller, and are therefore irrelevant to this investigation, in this report we use the abbreviation UWC throughout for simplicity.

Figure 1: Example of a lever frame signal box

Figure 2: Example of a signalling centre with control panels

Figure 3: Example of a signalling centre with computer workstations

Case studies

8 To illustrate the types of incident under investigation in more detail, this section presents exemplar case studies summarising information from industry investigation reports collected by RAIB.

User worked crossing irregularity

9 At 20:37 hrs on 14 June 2015, the signaller at Marshbrook signal box (a lever frame box) in Shropshire received a telephone call from a tractor driver requesting permission to cross at New House Farm UWC. At these types of level crossing, which are typically used to access private property such as farmland, some crossing users (usually those crossing with vehicles or livestock) are required to contact the signaller using a telephone at the crossing to find out whether it is safe to cross. The signaller checked for trains in the area and granted the tractor driver permission to cross.

10 However, on this occasion a train was approaching New House Farm UWC and passed over the crossing just after the tractor had cleared it. The train driver saw the tractor complete its crossing when the train was about 45 to 90 metres from the crossing. Maximum permitted line speed for the train at this location was 90 mph (145 km/h or 40 m/s).

11 The signaller believed the tractor driver was calling from Woodlands UWC, a crossing about six miles away from New House Farm UWC. The industry investigation report identified the causes of this incident to be associated with the signaller's attention and safety-critical communications. The report further observed that the layout of the buttons on the telephone concentrator unit in the signal box, which indicate where a crossing user is calling from, was potentially confusing.

12 In response to this incident, the industry report noted that the signaller had undertaken retraining and would undergo additional monitoring, while the arrangement of buttons on the telephone concentrator unit had been changed.

Line blockage irregularity

13 At about 10:43 hrs on 3 November 2014, a near miss occurred between a group of five track workers and a passenger train travelling at 102 mph (164 km/h), near East Langton in Leicestershire. The track workers moved clear of the line about two to three seconds before the train passed them.

14 The person responsible for the safety of the group of track workers had requested a line blockage for about 10 minutes with a signaller at East Midlands Control Centre (a workstation-based signalling centre). Line blockages are used for short-term protection of track workers, and rely on the signaller taking action to prevent trains from entering a defined section of line where the work is taking place. This is achieved by ensuring that the section concerned is clear of trains, placing protecting signals to red and then using reminder appliances (a physical or software device that prevents the signaller from setting routes from those signals).

15 The signaller in this case had misread the number of the exit signal for the line blockage on his display screen, mixing up signals LR224 and LR244. Consequently, he believed that the train involved had already cleared the section of line to be blocked, and granted the line blockage while the train was actually still in the section.

16 The industry investigation report noted issues with the signaller's use of reminder appliances on the workstation as well as his safety-critical communications. The report's recommendations included addressing these issues through rebriefing and monitoring, as well as a review of all signal panels and workstations nationwide for situations where similar signal numbering could lead to confusion.

Users trapped at CCTV level crossing

17 At 15:35 hrs on 12 August 2015, a pedestrian became trapped inside the closed barriers at Enfield Lock level crossing, north London. The pedestrian had been crossing while the barriers were lowering, the red lights flashing and the audible warning was sounding, and had not managed to exit the crossing before all the barriers closed. The pedestrian then walked into a corner of the crossing and remained there while two trains passed.

18 A similar incident occurred at the same location at 14:14 hrs on 2 September 2015, when the driver of a train passing over the crossing reported seeing a person inside the crossing barriers as the train passed.

19 Enfield Lock is an example of a full barrier level crossing, where barriers extend across the entire width of the road, preventing access to the railway. Many such crossings are controlled by a signaller using a CCTV image to view the crossing (figure 4). When a train approaches these crossings, the barrier lowering sequence is started (either automatically in response to the train passing over a detector at a given location or manually by the signaller). Once all the barriers are fully lowered, the signaller views the CCTV monitor to check that the crossing is clear and, if it is, presses a button that allows the protecting signal for the crossing to be cleared (pressing this button also usually switches off the CCTV monitor). Under normal circumstances, the crossing sequence should be timed so as not to impede the train's approach, by ensuring the signals are clear before they come into view of the train.

Figure 4: Photograph of the signaller's CCTV monitor for Enfield Lock level crossing

20 Enfield Lock level crossing is controlled from the Brimsdown workstation at Liverpool Street Signalling Control Centre (SCC). In both of the cases described above, the industry reports noted that the pedestrians' clothing meant that they were not conspicuous in the CCTV image. The reports addressed both signallers' attention and concentration as well as problems with the quality of the image on the CCTV monitor.

Irregularity involving a level crossing on local control

21 At 08:51 hrs on 7 August 2015, a passenger train passed over Tinsley's level crossing (a full barrier level crossing) near Spalding, Lincolnshire, before the barriers were fully lowered. A car approaching the crossing stopped in response to the flashing red road lights that had started just before the train passed over the crossing.

22 Tinsley's level crossing is controlled from Lincoln South workstation at Lincoln SCC, and uses obstacle detection technology instead of CCTV to confirm that the crossing is clear. Earlier in the day, a failure of signalling equipment meant that South Drove level crossing, about two miles beyond Tinsley's, had to be controlled locally by a level crossing attendant. It also meant that the signal protecting Tinsley's level crossing could not be cleared to show a proceed aspect, so although Tinsley's level crossing itself was otherwise working normally, the signaller needed to lower the barriers before authorising any movement towards it.

23 Before the train approached the protecting signal for Tinsley's level crossing, the signaller contacted the level crossing attendant with instructions to lower the barriers at South Drove level crossing in readiness for the passage of the train. When the train arrived at the signal, the signaller spoke to the train driver by radio to provide verbal authority to pass the signal while it was showing red. During this conversation, the signaller also advised the driver about the failure of South Drove level crossing and only to pass over the crossing when a green hand signal was shown by the level crossing attendant. No mention was made of Tinsley's level crossing, which the train would pass before reaching South Drove.

24 The industry investigation report concluded that the signaller overlooked the need to lower the barriers at Tinsley's level crossing, having been focused on the equipment failure at South Drove. The report also noted that the signaller did not use route cards, which are a way of ensuring that routes are correctly set when under conditions of degraded working.

Operational irregularity

25 At about 15:17 hrs on 14 December 2017, two passenger trains were involved in a near miss at Heaton Norris, near Stockport, Greater Manchester. The signaller at Heaton Norris (a lever frame signal box) had given both trains authority to pass signals at red without realising that these instructions would bring the trains into conflict with each other.

26 Before the incident occurred, the signaller had set routes for the passage of two freight trains to use crossovers to traverse the main lines at Heaton Norris Junction, taking the first from the branch line onto the up fast line, while the second was routed from the down slow onto the branch line (figure 5). The second freight train then developed engine problems and came to a stand on the branch line, physically clear of the main lines but not clear of the signalling section. This meant that it was impossible for the signaller to clear the signals for trains approaching on the up fast and up slow lines.

27 A short time later, two passenger trains approached on the up fast and up slow lines, both being stopped by the red signals protecting the junction. The signaller, who was feeling increasingly under pressure from the escalating situation, gave both drivers in turn verbal authority to pass the red signals. However, the crossover used earlier by the first freight train was still set for a movement from the up slow to the up fast line.

28 The driver of the train on the up fast line saw that the points were set incorrectly and stopped the train before reaching them. Meanwhile, the driver of the train on the up slow line did not notice the crossover until just before the train reached it, travelling at 30 mph (48 km/h), so the train continued through the crossover, narrowly missing the side of the other train (figure 6).

29 The industry investigation report identified numerous causal factors, including the signaller's distraction and time pressure in dealing with the failed freight train, sub-standard safety-critical communications, and the layout of equipment in the signal box which could have hindered the signaller's acquisition of critical information. It further cited concerns with signaller monitoring and competence management, associated with organisational problems at local management level. The report raised several local actions, largely directed at issues of training and competence management.

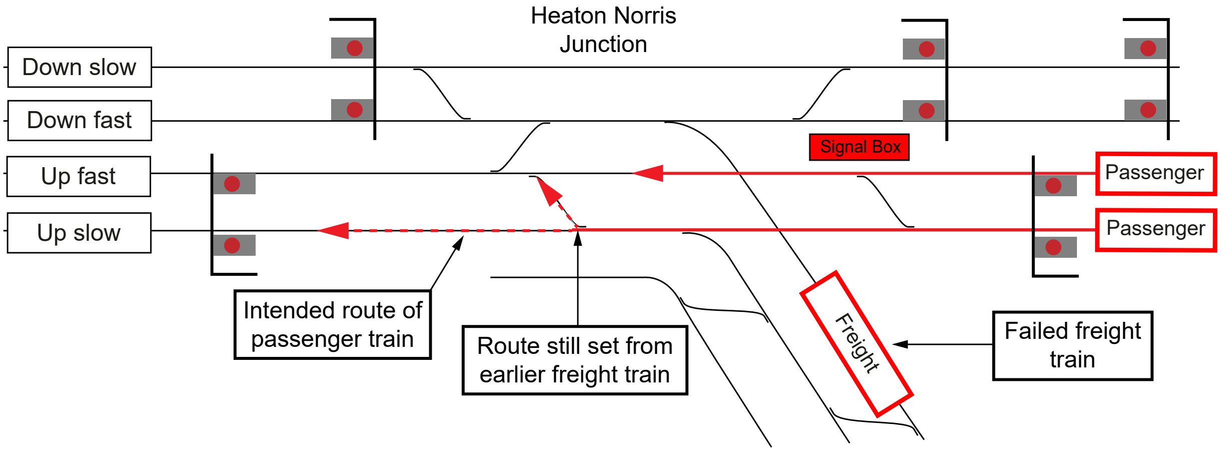

Figure 5: Diagram of the Heaton Norris Junction area, showing the trains involved in the incident (adapted from a Network Rail diagram)

Figure 6: Forward facing camera view of the near miss, taken from the train on the up fast line and showing the train on the up slow line passing over the crossover immediately ahead (image courtesy of CrossCountry trains)

Analysis

Method

30 Several data sources have been used for this class investigation. Over a period of five years (2014 to 2018), RAIB collected 19 industry investigation reports for notable incidents in each of the categories above, where the incident was of interest to RAIB, but did not meet RAIB's criteria[3] for an investigation. In addition, RAIB's own relevant investigation reports dating back to the start of its operations in 2005 (of which there were 20, as listed in Appendix D) were reviewed. From these reports, RAIB extracted the causal factors and classified them according to an industry standard human factors framework (set out in Rail Industry Standard RIS-3119-TOM; see paragraph 69 for further details).

31 To determine the wider extent of such incidents occurring, RAIB also searched the daily incident logs from Network Rail's National Operations Centre, also covering the five-year period from 2014 to 2018, and found 298 relevant incidents. Along with the reports, RAIB statistically analysed these sets of data (see paragraph 62) across the categories of incident and types of signalling location.

32 At its outset, this investigation also considered comparisons between operations on the national network and those of other UK railways (including light rail and metro). While there are inevitably echoes of concern around human decision-making elsewhere, the operational differences on these other railways (such as the absence of level crossings, or automatic signalling) made such comparisons difficult, and so RAIB did not take this element of the investigation further.

33 Finally, RAIB conducted observations of, and group interviews with, signallers at four locations representative of the incident reports collected (paragraph 30), and reflecting the three different types of interface technology (paragraph 7). The purpose of this was to gather evidence on real-world constraints and factors affecting signallers' decisions in the scenarios under consideration. Based on this field work, RAIB commissioned a human factors analysis of the work involved in signalling. Appendix E provides more detail on the method and outputs of this work.

Signalling work analysis

34 At a high level, signallers' work involves balancing three main priorities: maintaining safe operations, maintaining a punctual service, and facilitating the efficient delivery of track maintenance work (in other words, providing access and protection for track workers). Within these priorities are numerous sub-tasks, whose functions may complement or conflict with each other.

35 For instance, providing safe access for track workers contributes towards maintaining safe operations and the delivery of track maintenance, but can conflict with maintaining a punctual service. Therefore, signallers are only willing to grant a line blockage when there is a gap in the train service, so track workers might have to wait for a suitable window of opportunity.

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[3] https://www.gov.uk/guidance/raibs-response-to-accident-and-incident-notification#how-raib-selects-accidents-to-investigate.

36 Consequently, signallers often have to make implicit decisions about trade-offs between the demands of keeping the railway running and maintaining the safety of the system, within the constraints and resources available. Importantly, these decisions are made in a real-world context, and so are influenced by the signaller's perception, their own experience and expectations, as well as by rules, procedures and the objective reality of the situation.

37 Signallers may draw on a wide variety of information sources in making these decisions, including displays (such as the signalling panel or workstation screen), documents (rules and procedures, notices, forms) and people (other signallers, track workers, members of the public). However, not all of these sources are reliable or comprehensive all of the time.

38 The incidents being considered are therefore not solely the result of individual decisions or actions, but are instead part of an overall pattern of events and performance, influenced by contextual factors and system constraints. The following paragraphs describe these factors in more detail for each of the scenarios under investigation.

User worked crossings

39 The key sources of information for a signaller making a decision regarding a UWC are the signalling display panel, the telephone concentrator, and the user themselves. The signaller needs to know which UWC the user is calling from, what they are crossing with (such as type of vehicle, animals, or other details), and how long they need to cross. They then need to decide whether there is enough time for the user to cross before any trains reach the crossing.

40 Information about which UWC the user is calling from is available on the telephone concentrator and through the conversation with the user. Problems have been identified in previous incidents with the labelling of buttons on the concentrator (for instance, using different crossing abbreviations to those shown on the signalling display) or the layout of the buttons (see, for example, paragraph 11). The crossing user, on the other hand, might use a different name for the crossing (typically a local variation to its formal name as used by the railway).

41 The signaller is entirely dependent on the user for information about what they are crossing with and how much time they need. Such information can be variable; users might refer to their vehicle informally (for example, a 'wagon' was used to describe a 60.5 tonne articulated unit in an incident at Bagillt UWC on 17 August 2018; see RAIB report 11/2019). Users also typically underestimate the time it will take to cross. Signallers often need to make their own judgements based on a level of confidence in, and interpretation of, the information provided by the user.

42 The critical decision concerns whether there is enough time for the user to cross well before any trains reach the crossing. The signaller is now wholly dependent on the signalling display (or other indicators of the state of the line) to determine the location of any trains in the vicinity of the crossing, and judge how long it will take those trains to reach the crossing in the context of the time required by the user. These so-called 'decision points' are not generally standardised or formally trained, but are largely derived individually through experience and learning from other signallers' practices. The decision may be particularly complicated by long track sections on the signalling display, which make it difficult to establish a precise location for the train (see, for instance, RAIB's investigation of an incident at Dock Lane UWC on 14 June 2016; RAIB report 08/2017).

43 One of the key trade-offs that signallers have to consider in the UWC decision process is the amount of time that a user will have to wait as a result of any decision to refuse permission to cross. Clearly, the safest decision is to refuse permission if there is any chance of a train approaching the UWC while the user is in the process of crossing. However, if the waiting time becomes too long, there is a risk that a user might decide to cross anyway, particularly if there is apparently good sighting along the railway line. Signallers therefore balance a margin of safety against this risk.

Line blockages

44 According to a report[4] by the Infrastructure Safety Leadership Group (ISLG), incidents involving trains incorrectly entering line blockages and possessions are the highest risk faced by track workers. The report further highlighted the overreliance on human performance as a sole control for this risk, with critical aspects of the signaller's task being identified as setting up the blockage in the correct location and setting routes for other trains around the blockage.

45 In implementing a line blockage, the signaller is largely dependent on documentary information about the planned block (in notices, forms etc) and telephone conversations with the track worker who is taking the line blockage at the site of work. As with UWC decisions, the key factor is identifying a suitable window of opportunity between trains to provide the time requested by the track workers for the line blockage. Such windows are increasingly difficult to find as train services become ever more frequent to meet the operational demands of the railway. Ironically, more rail traffic means increased need for maintenance due to wear on the tracks, but less opportunity for track workers to access the railway.

46 Signallers were critical of the forms used for setting up line blockages, with wide agreement that the forms are complex and time-consuming. Along with the task of applying reminder appliances on the controls for protecting signals, signallers felt that this whole process can sometimes take longer than the actual time required for the line to be blocked – or even that they might miss a suitable gap in the train service while filling in the forms.

47 Dealing with line blockages increases workload for the signaller. As such, many signalling locations only permit one line blockage at a time per signaller. Much of the additional workload is in setting up and taking down the line blockage, rather than during the line blockage itself, so multiple consecutive line blockages of short duration can be much more demanding than one long blockage.

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[4] 'Track Worker Safety in Line Blockages and Possessions: Summary Report and Conclusions', Issue 1, 4 May 2018. Infrastructure Safety Leadership Group.

48 One consequence of high workload can be a negative impact on the standard of safety-critical communications between signallers and track workers. Nonetheless, RAIB's investigation of an operational irregularity at Balham on 20 April 2019 (RAIB report 01/2020) highlighted a general problem with the standard of communications between signallers and track workers. Signallers are expected to lead the conversation and set the standard regarding verbal protocols, but the Balham investigation showed that these standards can drop when interacting with track workers.

CCTV level crossings

49 The signaller's actions in dealing with a manually controlled CCTV level crossing include starting the crossing closure sequence, checking that the crossing is clear when the barriers are closed, and pressing a 'crossing clear' button to allow the protecting signal for the crossing to be cleared. In checking that the crossing is clear, the signaller is wholly dependent on the CCTV monitor view of the crossing.

50 The quality of the image on the monitor is therefore critical to this task. Although there is a Network Rail standard[5] governing the requirements for camera positioning at the crossing, RAIB notes that camera angles can vary considerably between different crossings (figure 7). In addition, the quality of the image is dependent on several other factors such as the size and clarity of the monitor screen and environmental conditions at the crossing (particularly rain or sunlight).

51 There is not normally a requirement for signallers to watch the barriers during the lowering sequence;[6] sometimes, a signaller may be engaged with another task (such as operating a different crossing or setting a route for a train) while this is occurring, and return their attention to the screen when the barriers are closed. However, this raises the possibility of a phenomenon known as 'change blindness', in which a signaller might not notice the presence of a change (someone on the crossing) if they did not see that change occur (the person moving onto the crossing). Moreover, characteristics of human vision mean it is easier to detect movement than a static image (such as of someone who has retreated to the corner of a crossing).

52 Signallers are trained to use a 'figure-of-eight' scanning technique when checking the CCTV monitors. With experience, some signallers adapt this by pausing their sweep at set points in the scan to try and detect movement, as well as particularly focusing on known blind spots or hiding places on the crossing.

53 The behaviour of crossing users is also a factor in signallers' decisions. Again, experience plays a key role in picking up on implicit behavioural cues that might indicate a user's intention to cross while the barriers are closing. As with UWCs, signallers also have to balance the requirements of the train service against the need to minimise the time that crossings are closed to road traffic and pedestrians; in some locations, this type of crossing can be closed for relatively long periods, causing significant disruption to the local community.

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[5] NR/L2/SIG/11201/Mod X23 Signalling Design: Module X23 – Level Crossings: Manually Controlled barriers With Closed Circuit Television (Issue 1, 3 September 2011).

[6] Local instructions, based on identified risk, require the signaller to always observe the lowering sequence at some crossings.

Figure 7: Photograph of the signaller's CCTV monitors for Enfield Lock level crossing (Liverpool Street SCC; top) and Ickleton Road crossing (Cambridge signal box; bottom)

54 At some signalling locations, the crossing controls and CCTV monitors have been separated from the main signalling control panel onto a dedicated crossing desk, operated by a different signaller. These have the desired effect of reducing workload for the signaller on the panel, but signallers also reported that this reduces their level of control and increases demands on coordination and communication with the signaller on the crossing desk.

Level crossings on local control

55 Under some circumstances, such as a failure of signalling equipment or during maintenance work, a level crossing may need to be controlled locally by a level crossing attendant using controls at the crossing itself. As a degraded mode of operations, this process is highly dependent on effective verbal communications between the signaller and both the level crossing attendant and train drivers who are being authorised to make a movement over the crossing. These additional communications increase workload on the signaller.

56 It is crucial that the signaller establishes a shared understanding with the level crossing attendant to ensure the barriers are closed for each passage of a train. This is especially true if two trains are passing in quick succession. However, there is no set form of words for such communications; signallers develop their own script.

57 As well as the increased communications workload, signallers can be provided with less information in these circumstances, because CCTV images for manually controlled crossings and annunciators alerting signallers to the approach of a train may not be available when the crossing is on local control, depending on how the equipment has been configured. Moreover, on workstation-based signalling displays, information concerning the status of level crossings on local control may not be conspicuously presented or positioned. This was highlighted in a RAIB investigation of a near miss at Ufton crossing in Berkshire on 4 September 2011 (RAIB report 28/2012).

Operational irregularities

58 As defined in this investigation (paragraph 6), an operational irregularity could arise from any kind of train movement under normal, abnormal or degraded signalling operations. As a result, in order to analyse the work associated with operational irregularities, it was not possible to focus on a specific scenario, as was the case for the other four categories of incident. Therefore, RAIB widened its focus here to consider more general activities and tasks associated with signalling.

59 The information sources routinely available to signallers include the signalling display, the working timetable, weekly operating notices, special traffic notices, knowledge of train reporting numbers (headcodes, which are shown on panel displays and workstations), and communications with people (such as signallers of adjacent areas, train drivers, station staff, or route control[7]). Problems can arise either with the source of the information itself, or the signaller's understanding of that information.

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[7] The Network Rail organisation in each Route responsible for monitoring the operation of the railway and coordinating any action required when out-of-course events occur.

60 Signallers draw heavily on their own experience in regulating and routeing trains. For instance, knowing the amount of time it takes for a train to traverse a signal section, or between station stops, can be invaluable in determining how to prioritise traffic.

61 The nature of the signaller's work is also changed by automatic route setting (ARS), which is typically (although not exclusively) associated with workstation-based signalling centres. ARS uses timetable data to automatically regulate trains by setting routes on behalf of the signaller. Under normal circumstances, then, one signaller with the support of ARS can control a much greater volume of traffic than they would be able to without ARS. However, if the signaller has to intervene and override ARS (for instance, because of inaccuracies in the timetable information upon which it depends), this can generate extra workload (similar concerns have been raised by the trade union[8] that represents many signallers). Another impact of such automation is a sense of detachment from the work of signalling, because signallers are less actively involved in the task and receive limited feedback about the system's decisions and actions. Signallers sometimes use non-standard strategies to 'control' what ARS does, such as placing reminder appliances on signal controls to prevent ARS from using certain routes.

Statistical analysis

62 Figure 8 summarises the number of incidents in each category, reflecting the data for RAIB investigation reports, industry investigation reports, and items found in the daily incident logs. The graphs show a much larger proportion of line blockage irregularities in the incident logs than are reflected in the investigation reports; many of these, though, did not result in a near miss with track workers. The investigation considered only those line blockage incidents in which the actions of signallers were relevant.

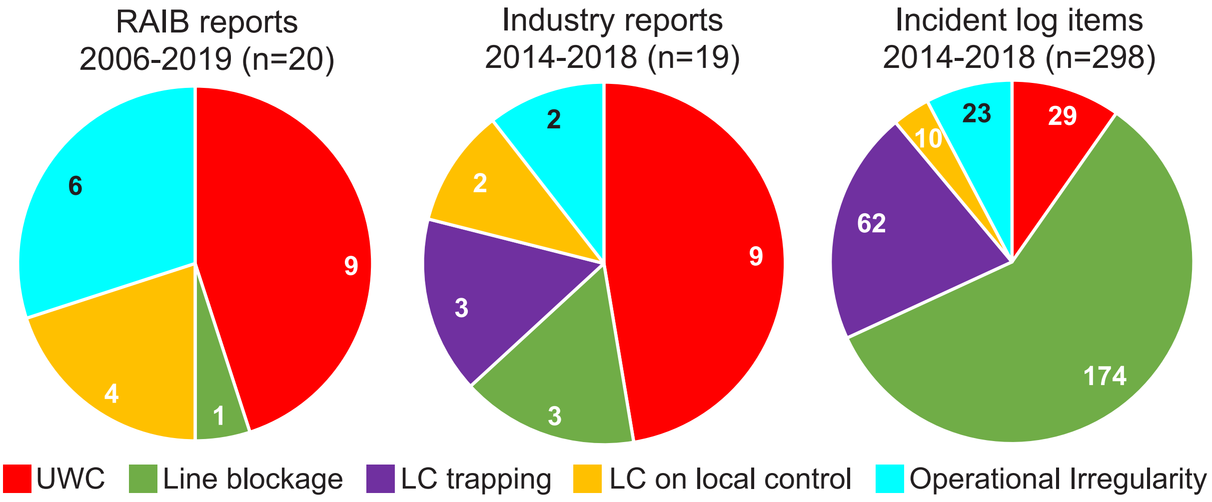

Figure 8: Descriptive data for number of incidents in each category across RAIB reports, industry investigation reports, and daily incident log items. Notes: (1) UWC = user worked crossing irregularity, LC = level crossing; (2) there are no RAIB investigation reports of trapping incidents at CCTV level crossings.

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[8] https://www.rmt.org.uk/about/health-and-safety/health-and-safety-circulars/safety-related-incidents-and-signaller-workload-increase270120/.

63 Taking the entire pool of 337 incidents in the three graphs above, RAIB further analysed the data according to type of signal box (lever frame, panel or workstation) to determine whether there was any association between type of signal box and category of incident. The results are presented in figure 9.

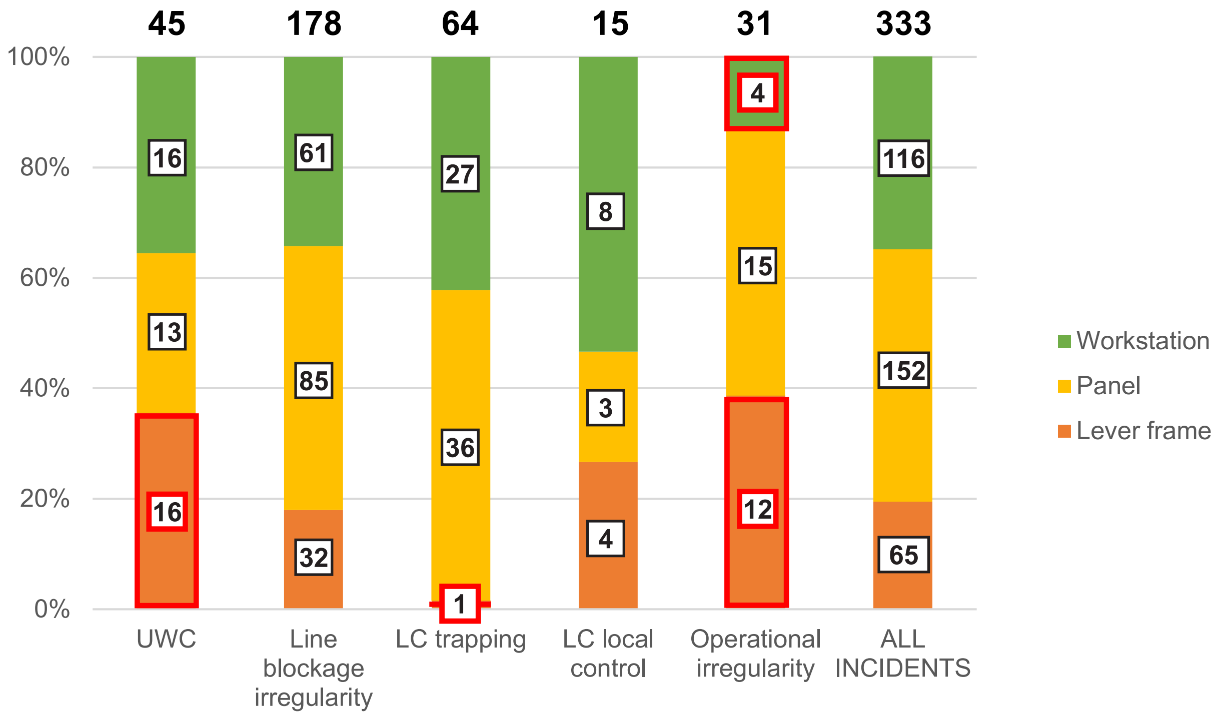

Figure 9: Graph showing the total number of incidents in each category divided according to type of signal box. Statistically significant results are outlined in red. Totals for each column are shown across the top of the graph.

64 Finally, RAIB carried out statistical analysis of the data to compare whether the number of incidents in each category for each type of signal box was proportionate to the totals of all incidents (shown in the rightmost column and across the top of each column in figure 9). This has enabled RAIB to identify those cases where the number of incidents of a particular kind is statistically higher than might have been expected on the basis of the total number of incidents recorded in each type of signal box (by way of example, 19.5% of all incidents that were analysed took place in lever frames, whereas 35.6% of incidents at user worked crossings involved lever frames).

65 The results suggest that in lever frame signal boxes, there were more UWC irregularities (possibly due to the inferior presentation of train position information as compared to the other types) and operational irregularities than expected, while there were fewer than expected trappings at CCTV level crossings (probably because there are few lever frame signal boxes that control CCTV level crossings). Meanwhile, there were fewer than expected operational irregularities at workstation-based signalling locations (possibly because ARS is associated with workstation-based signalling). However, it is important to note that some of these results may simply reflect differential baselines (such as numbers of UWCs supervised from different locations) in the underlying dataset, which were difficult to separate out.

66 The analysis above is based only on the dataset of incidents collected for this investigation, so the observed variations indicate proportionate differences where those incidents have occurred, and do not necessarily reflect overall performance across the three types of signal box nationally. Such a comparison is difficult due to the accessibility of accurate baseline data (such as numbers of signalling locations, or numbers of level crossings supervised from a given location) against which to normalise the statistics. Nevertheless, a limited analysis is possible by factoring in the approximate numbers of signal boxes and centres cited earlier (paragraph 7).

67 Unsurprisingly, this analysis suggests that lever frame signal boxes are underrepresented in these incidents, whereas panel boxes and workstation-based signalling centres are overrepresented (the large number of lever frame signal boxes still in existence swamps the analysis). In fact, operational irregularities is the only category for which incident numbers seem to be proportionate to overall signal box numbers. Again, these results must be interpreted with caution, since there are many other variables that should be taken into account. For instance, as noted at paragraph 7, each workstation-based centre houses multiple workstations, covering a larger geographical area than a traditional lever frame signal box. Not only does this have the kinds of statistical impact described above, but it also affects the work of signallers in terms of factors such as workload (see also paragraph 80). Aggregating data in this way also sacrifices details associated with specific locations, such as the particularly high number of UWCs in some areas (see, for instance, RAIB report 08/2017). On balance, though, RAIB decided that this choice of analysis entailed the least compromise in providing context to the statistics.

Analysis of rail industry incident factors

68 One of the main objectives of this investigation was to understand common factors influencing the actions of signallers across the scenarios under consideration. This was achieved by, firstly, categorising the causal factors from previous reports (paragraph 30) against an industry standard classification scheme, as detailed in this section. Subsequently, RAIB used all of the evidence gathered so far to extract the most significant factors affecting signallers' performance (see paragraph 74).

69 For the incident factor analysis, RAIB used the human factors framework set out in Rail Industry Standard RIS-3119-TOM (note that this analysis was based solely on the information available in the reports). The framework classifies incidents initially as one of four human performance factors, then allocates further categories as appropriate from the following 10 incident factors:

a. verbal communication

b. fatigue, health and wellbeing

c. processes and procedure documents

d. written information on the day

e. competence management

f. infrastructure, vehicles, equipment and clothing

g. the person's environment
h. workload (real or perceived) and resourcing
i. teamworking and leadership
j. risk management.

As can be seen in the list above, the 10 incident factors relate to underlying, organisational issues. Since the current investigation is also concerned with such issues, the following analysis focuses on these factors rather than the initial human performance classification in the rail industry standard (although RAIB did apply that classification to arrive at the 10 incident factors).

70 In extracting the performance influencing factors significant to this investigation (see paragraph 74), RAIB found that these 10 categories did not fully account for the evidence collected. Therefore, for the purposes of the present analysis, a factor of 'experiential knowledge' was added to the list of 10 factors above. This factor is explained further in paragraph 95, but in summary it consists of the informal strategies, information and knowledge, beyond formally documented procedures, that are used by experienced signallers. Although such knowledge would normally be seen as part of 'competence management' in the industry's list of categories, it was treated separately for the purposes of this class investigation due to its prevalence in the incidents reviewed. Meanwhile, evidence relevant to some of the other factors aligned with particular aspects of the original definitions. Specifically, RAIB's classifications of 'infrastructure, vehicles, equipment and clothing' referred primarily to equipment design issues, 'teamworking and leadership' included organisational issues associated with the Local Operations Manager (LOM) role (see paragraph 100), and 'risk management' covered the problems identified with user-centred design in the management of change (see paragraph 81). The analysis that follows reflects these applications of the industry standard definitions.

71 Figure 10 shows the results of this analysis, totalled across all 39 of the RAIB and industry investigation reports reviewed. The results largely confirm the significance of the factors identified in this class investigation, with the top three categories being, in order of frequency: experiential knowledge, equipment, and workload. Experiential knowledge was particularly prominent in workstation-based signalling centres, and in UWC irregularities. As stated above, this factor is not treated as an independent category in the industry's framework, suggesting that, in this case, there is an important sub-factor within 'competence management' which may be overlooked in a more general analysis.

72 The factors associated with the management of change (risk management) and organisational structure (teamwork) were less prominent in the incident data, which suggests these factors may not be as causally relevant as perceived by front-line staff. There are possible alternative explanations, though. The results for these factors could have been affected by a coding mismatch in attempting to fit the observed factors to the existing categorisation. Alternatively, this finding could perhaps reflect a disinclination of the investigations to explore these deeper factors, whether due to a lack of understanding of the issues or because the scope of the investigation was limited.

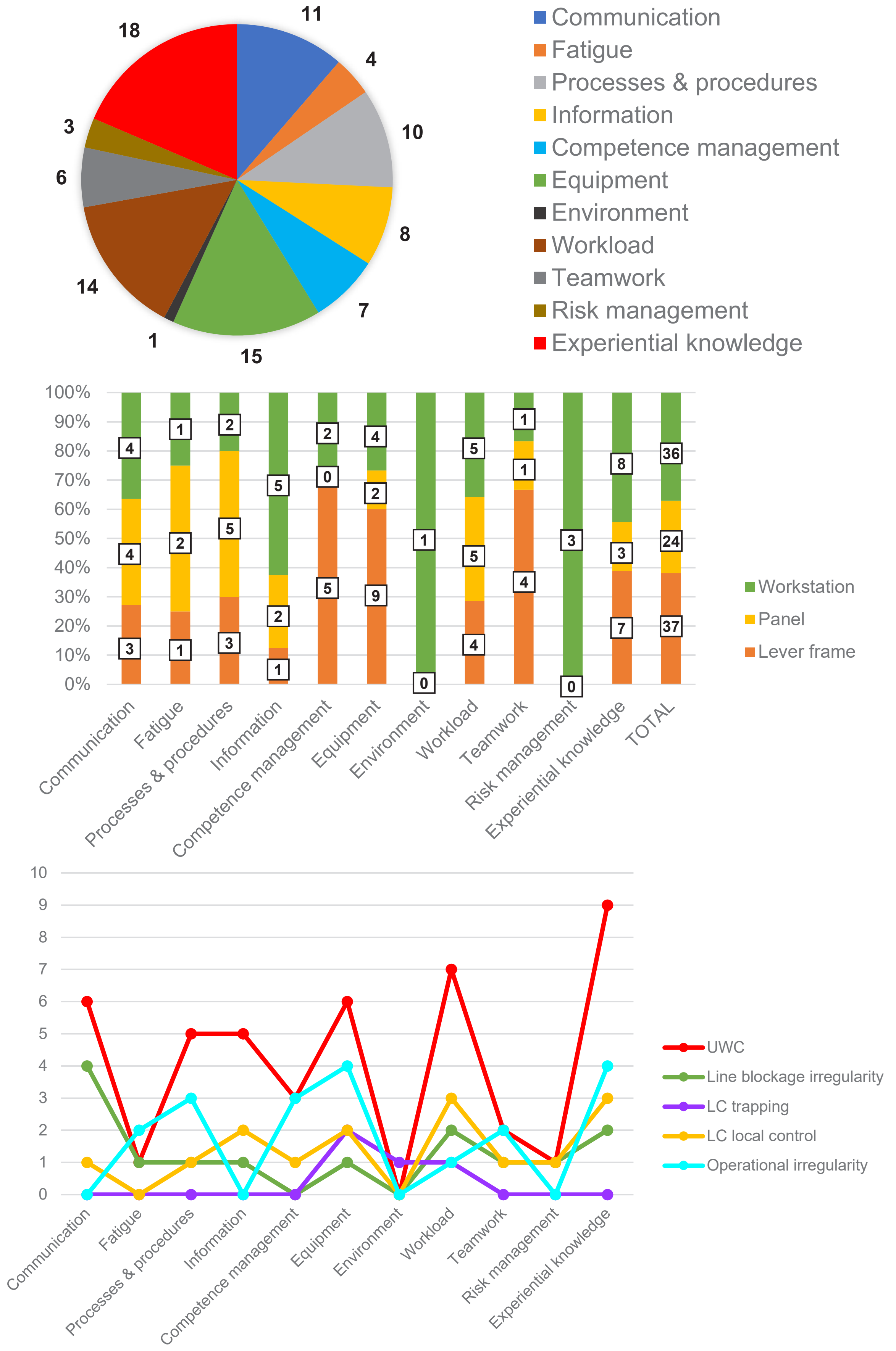

Figure 10: Graphs showing incident factors as classified by RAIB, representing totals across RAIB and industry investigation reports (top), divided by signal box type (middle), and divided by incident type (bottom)

73 In addition, RAIB further used these incident classifications alongside the work analysis presented above to develop an ‘AcciMap’[9] representation of the causal factors across these investigations. For this investigation, each category of incident was represented as an ‘outcome’ at the bottom of the AcciMap diagram, with all the factors identified in the reports placed in the relevant levels on the system hierarchy. These factors were then linked to the outcomes either directly or indirectly (direct links are colour coded with their respective outcomes), again according to evidence as presented in the reports. As seen in figure 11, the AcciMap diagram helps to further illustrate the relationships between factors and incident categories. In particular, the five main factors identified in this class investigation are distributed across the levels of the analysis, highlighting the fact that none of the incidents have a simple ‘root cause’, but reflect a complex interaction between people and contextual factors of the organisation.

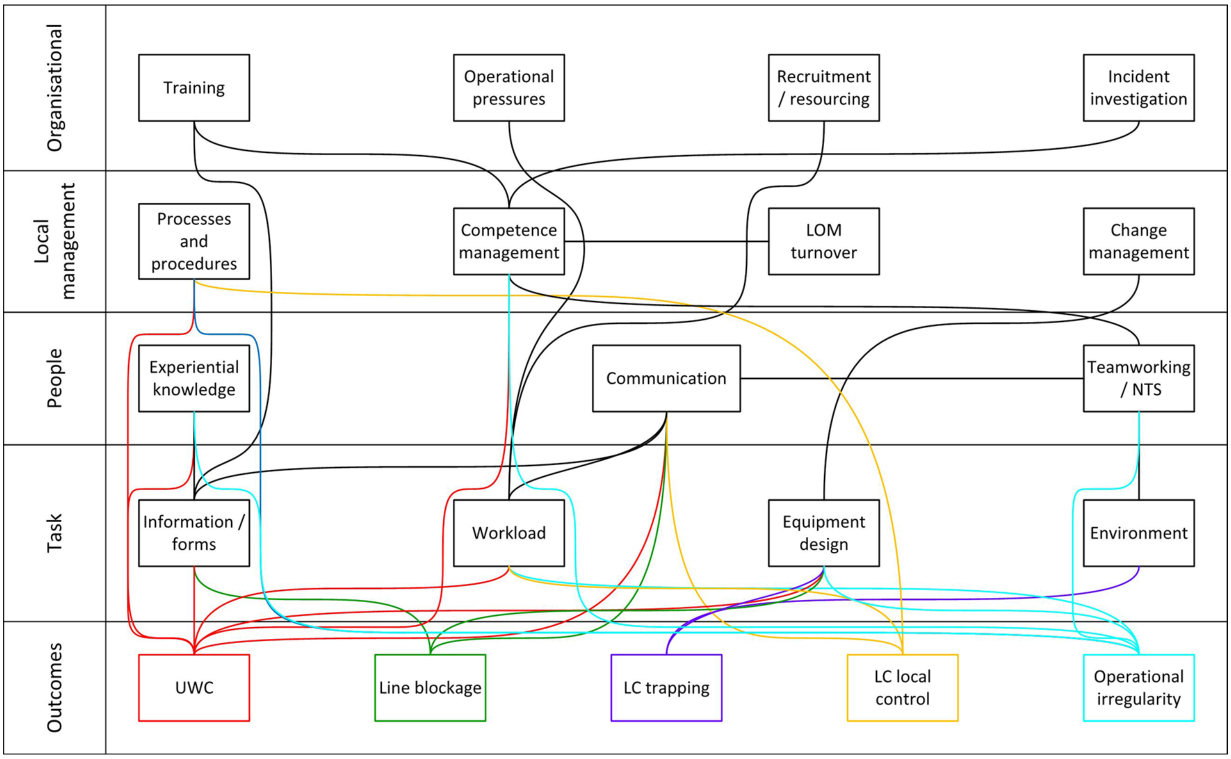

Figure 11: Accimap representation of causal factors across incidents

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[9] Svedung, I. & Rasmussen, J. (2002) Graphic representation of accident scenarios: mapping system structure and causation of accidents. Safety Science, 40(5), 397-417; see also Rail Industry Standard RIS-3119-TOM for a description of the process applied to rail accident and incident investigation.

Identification of common factors

74 Based on all of the preceding analyses, RAIB identified a subset of the 10 incident factors (plus the additional factor of experiential knowledge already noted) as being particularly significant influences on signaller decision-making and therefore playing a stronger role in the causation of an incident or accident. In identifying these factors, RAIB combined the evidence from the work analysis (paragraph 33), the statistical analysis (paragraph 62), and the incident factor analysis (paragraph 68), giving equal weight to each source of evidence. As a result, the five factors listed below do not precisely match with the five most frequent factors from the incident factor analysis. These five factors, with their equivalent categories from the 10 incident factor framework in brackets, were:

a. signaller workload [workload] (paragraph 75)

b. user-centred design [risk management] (paragraph 81)

c. competence management [competence management] (paragraph 87)

d. experiential knowledge [no equivalent category] (paragraph 95)

e. organisational structure [teamworking and leadership] (paragraph 100).

In keeping with the overall aim of this class investigation, these factors focus on aspects of the wider work system (paragraph 5) that provide the context for the day-to-day activities of signallers. Each of these factors is now considered in turn.

Signaller workload

75 **Network Rail's management of signaller workload does not fully reflect the complex cognitive demands of modern signalling centres.**

76 Signaller workload was a key factor identified in RAIB's work analyses. Contributors to workload include not just the primary demands of regulating train movements, but also the ancillary tasks of signalling such as communications, providing protection, and completing paperwork. In general, signallers' workload has increased in recent years with busier train timetables and the associated demands for track access (paragraph 45).

77 This investigation found that signaller workload is particularly affected by the competing demands of concurrent scenarios and interactions between events. Peaks in workload from dealing with one task can have repercussions across other tasks. Dealing with unanticipated events or degraded modes of operations, which are central parts of the signaller's role, can also increase workload. Signaller performance is particularly vulnerable in these situations as excessive workload can adversely affect decision-making and communications. This can be particularly true if workload suddenly increases following a period of underload.

78 Network Rail aims to control workload proactively in the design of signalling panels and workstations by determining a manageable area of control for a given signaller according to its in-house workload toolkit. The toolkit consists of several methods, which are based on subjective reports (by signallers), observations, or task-based assessments. Where appropriate, Network Rail also takes reactive measures designed to manage workload, such as separating level crossings from a signalling panel (paragraph 54), or restricting the number of simultaneous line blockages (paragraph 47). These actions may be based on similar workload assessments using the toolkit.

79 For front line staff, the approach to managing signaller workload focuses primarily on individual signallers, through the recruitment and selection process (by assessing the capabilities of applicants to cope with the demands of the job), or through development in non-technical skills (NTS), which place the responsibility on signallers to manage their own workload. Signaller NTS are defined[10] as a set of behaviours, personal skills and attitudes that Network Rail expects an employee to demonstrate. This includes areas such as attention management, multi-task capacity, and being controlled under pressure. While this may be the most practicable approach to managing workload, RAIB considers that the prime determinant of workload is the nature of the work or the task being undertaken, and it is therefore not a factor that is generally under the control of the individual. Ideally, workload should be managed by organisations seeking to understand and adapt the work itself, rather than trying to adapt the individual staff member to the work.

80 The signaller's task has evolved with the development of workstation-based signalling control, such that the work is increasingly cognitive in nature. Technology has allowed signallers to control more trains over wider geographic areas with little impact on observable activity. However, this increase in information has been at the expense of greater thinking, planning and monitoring demands on the signaller (as described at paragraph 61). Although subjective workload assessments can provide insight into some of this unobservable demand, such techniques are only possible for existing signalling locations. The remaining methods in Network Rail's toolkit, which are primarily used to model and predict workload for new or modified workstations, are not suited to determining this cognitive workload. Consequently, the actual demand on signallers may be underestimated.

User-centred design

81 **Network Rail's management of change does not consistently involve signallers in decisions about equipment or processes that affect their work.**

82 The principle of user-centred design takes account of end users' requirements and preferences in the design process, with the aim of improving usability and overall performance. While it does not ask users to actually design the system (because there are many other constraints on the design process), feedback from a representative sample is actively sought and incorporated throughout the design process.

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[10] NR/L3/OPS/045/2.06 Network Rail National Operating Procedure 2.06 Competence Standard and Assessment Framework for Operating Signalling Equipment, Issue 2, 2 June 2017.

83 Signallers reported a number of occasions when the implementation of a change to equipment or process resulted in problems that could have been avoided if the signallers themselves had been consulted about the change. Examples included poor interface design and equipment layout in workstation-based signalling centres. Network Rail has an ergonomics standard[11] to ensure user requirements are integrated into infrastructure, system and equipment design projects, but minor changes to displays do not trigger the application of the standard. The evidence suggests that in some cases, changes are being made that do have an impact on signaller performance, yet the user requirements are not being adequately addressed. Within the scope of its investigation, RAIB has not been able to determine whether this is because such cases were outside the scope of Network Rail's standard, or that the standard was not properly applied when it should have been.

84 In its investigation of an accident at Hockham Road UWC on 10 April 2016 (RAIB report 04/2017), RAIB found that representations from signallers about the number of display screens necessary to operate a new workstation were not taken into account. Consequently, fewer screens were installed than were either requested by signallers or recommended by an ergonomics assessment. After the accident, additional screens were installed beyond the original request.

85 Other industry reports provide further evidence for this factor. An inspection of Network Rail's Anglia route by the Office of Rail and Road (ORR), as part of a national intervention on signaller error risk management (see paragraph 145), found a number of issues with equipment design of new workstations which 'could probably have been avoided by more 'hands-on' involvement of signallers in the equipment design process'. ORR's report proposed an action for Network Rail to involve signallers' representatives directly in the design process when changing signallers' equipment.

86 Meanwhile, Network Rail has instigated a programme of its own in response to an increase in significant incidents caused by signallers (see paragraph 139). Its reports note a lack of effective consultation with signalling staff or their managers when implementing change. At York SCC, for instance, staff were engaged at an early stage regarding screen layouts, but the final implementation did not reflect their feedback and was not optimal from an end user perspective.

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[11] NR/L2/ERG/24020 Engineering assurance arrangements for Ergonomics within design and development projects, Issue 3, 3 December 2011.

Competence management

87 **There are shortcomings in Network Rail's competence management arrangements for signallers.**

88 There is widespread concern among signalling LOMs[12] regarding the training of newly-recruited signallers at Network Rail's signalling schools. Evidence suggests that trainees emerge from signalling school with variable levels of competence, which may be due to the range of backgrounds that new trainees come from. Nevertheless, any training gaps need to be addressed locally by LOMs, which increases their workload. In turn, this affects the quality of ongoing competence management, which is a factor that has been linked to some incidents (see also paragraph 100).

89 Network Rail's national operating procedure for signaller competence (see footnote 10) sets out the framework for competence management, which includes initial signaller training (signalling school) followed by a period of local training under the supervision of a competent signaller. The initial training is aligned to the Level 2 Infrastructure Operator Apprenticeship, which covers signalling principles, rules and regulations as well as the operation of signalling equipment and information systems.

90 Signalling schools therefore provide generic training on signalling rules and principles, but cannot cover the operational differences specific to several hundred locations. Network Rail's position is that signallers leave signalling school as 'trained but not competent', with local training plans designed to cover application of the core principles. Since LOMs are accountable for signallers' competence, managing these plans has always been an integral part of the LOM's role.

91 However, many LOMs are not specifically qualified or experienced to provide such training and assessment, and they do not receive training in management skills. An internal review conducted by Network Rail in 2018 found numerous issues with the signaller competency assessment process that had been recurring for several years. This confirmed that a significant proportion of those undertaking assessments and verifications of signallers' competence management did not hold a recognised qualification to do so, contrary to Network Rail's own procedures. Internal verification (quality assurance) of signallers' assessments was generally undertaken by the assessor's own line manager, with few processes in place to provide independent assurance.

92 The national operating procedure also details the non-technical skills framework and process for assessment, but provides little guidance on creating a development action plan for a signaller needing NTS support. Signaller NTS is often identified as a causal factor in Network Rail's incident investigations (see paragraph 111). LOMs have received training in understanding and identifying signallers' NTS, and were positive about this training. However, where a NTS issue is identified with a signaller, LOMs felt that they lacked the tools or knowledge to enable them to address that issue.

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[12] LOMs manage the day to day operation of a given area of Network Rail infrastructure, and have line management responsibilities for Mobile Operations Managers (who are a first line response to operational incidents) and signalling staff, including crossing keepers, signallers and Shift Managers (who supervise signalling operations on a given shift).

93 Because LOMs themselves may also be required to work at different signalling locations at short notice (for instance, to cover signaller absence), they also need to maintain their competencies for those locations. However, Network Rail's internal review found little evidence that LOMs are assessed to work signalling locations as part of their competence assessments. RAIB's investigation of a derailment at Knaresborough on 7 November 2015 (RAIB report 16/2016) also raised the issue of a relief signaller (a Mobile Operations Manager in that case) not maintaining an adequate degree of competence due to infrequently working signal boxes.

94 In some of the larger signalling centres, simulators are available for training purposes. However, this investigation found that some of these simulators tend to be underused, with only new signallers and those on development plans being trained in them. Simulators provide a range of opportunities for refreshing and updating the skills of all signallers (especially those who infrequently operate signalling equipment, or for situations which are rarely encountered), as they offer a safe environment in which various scenarios can be created and repeated. In its investigation of a derailment at East Somerset Junction on 10 November 2008 (RAIB report 28/2009), RAIB recommended that Network Rail make greater use of simulation to help signallers and controllers maintain their competence for infrequently encountered situations. More recently, in RAIB's investigation of an operational irregularity at Balham on 20 April 2019 (RAIB report 01/2020), witnesses reported a lack of opportunity for signallers to practise safety-critical communications in a safe training environment; again, a simulated environment would meet these needs.

Experiential knowledge

95 **Network Rail's procedures and training for operating railway signalling do not sufficiently account for the information, strategies and knowledge used by experienced signallers.**

96 Perhaps the most significant component of signaller decision-making is their own experiential knowledge, which comprises both local, geographical knowledge of their area as well as a less tangible representation of the task itself (which may include service patterns, infrastructure and equipment, or relationships with people). Signallers' decisions are based not only on an understanding of the railway rules, but also their extended experience of local conditions and different operational scenarios. Therefore, this knowledge has a profound effect on the strategies that signallers use and the decisions that they make.

97 The prominent role of such knowledge was clear across most of the scenarios in this investigation. Along with evidence of a link between operational irregularities and inexperience of signallers, there were numerous examples of local idiosyncrasies that experienced signallers were aware of but inexperienced signallers were not. Some of these examples had come to light through operational incidents, whereas in other cases signallers had developed their own strategies to improve efficiency around the equipment or procedures.

98 Research by Network Rail[13] suggested that only about half of such knowledge is imparted through organisational documentation (instructions, procedures etc), with the rest derived informally through experience. This informal knowledge is the basis for signallers developing heuristic strategies to deal with the various situations that they face.

99 Despite the clear importance of experiential knowledge, it is not formalised in signaller training. To some extent this is by definition – experience is, necessarily, gained over time, and signallers develop individual strategies that work best for them. Nevertheless, research into the psychology of expert decision-making[14] has shown that some types of training (such as simulation or other operational exercises) can accelerate the process of gaining experiential knowledge. Signallers told RAIB that they have limited opportunities to develop experiential knowledge, whether relating to local geography (for instance, through train cab rides, or visits to level crossings) or out-of-course events (using simulation), although some strategies are shared between signallers (either through mentoring or, in larger signalling centres, through ad hoc support from others). Relying on the informal development of experiential knowledge to close gaps in training or procedures may introduce vulnerabilities for tasks that are performed infrequently, or inconsistencies in ways of working between different signallers.

Organisational structure

100 **Local management structures within Network Rail adversely affect the competence management and professional development of signallers.**

101 In the industry investigation report for the Heaton Norris incident (paragraphs 25 to 29), competence management of the signaller was identified as a factor, which in turn was linked to high turnover of LOMs at that location.

102 Evidence suggests that the LOM role is widely perceived as unattractive, often with lower pay than signallers (primarily because signallers are paid overtime and shift allowances, whereas LOMs are not) and a multiplicity of duties resulting in excessively high workload (a Network Rail report estimated that even the baseline activities of an average LOM entail a 68-hour working week). Consequently, progression into the LOM role from signaller grades is rare and turnover of LOMs in the business is high (44% in 14 months, according to the same Network Rail report).

103 Recruitment of LOMs with both operational experience and management capability is therefore difficult. The post is seen as a route into the management structure within the business. Network Rail's internal review report also cited a lack of a framework for operational management competency; LOMs receive little or no formal training in management skills, training or assessment.

104 Organisational inefficiencies with recruitment and resourcing of signallers exacerbate the workload issues, as many locations seem to be perennially short-staffed. This creates potential conflicts of interest associated with assessing signallers' competence by their line management, as pressure to ensure signalling locations are suitably staffed can influence competence decisions.

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[13] Pickup, L., Balfe, N., Lowe, E. & Wilson, J.R. (2013). "He's not from around here!" The significance of local knowledge. In N. Dadashi, A. Scott, J.R. Wilson & A. Mills (Eds.), *Rail Human Factors: Supporting Reliability, Safety and Cost Reduction* (pp. 357-366). Boca Raton, FL: CRC Press.

[14] See, for instance, Crandall, B., Klein, G.A. & Hoffman, R.R. (2006). *Working Minds: A Practitioner's Guide to Cognitive Task Analysis*. Cambridge, MA: MIT Press.

Observation

105 Network Rail's incident investigations do not always fully identify or exploit the opportunities to learn from those incidents.

106 Network Rail's investigations involving signallers are typically carried out by LOMs, who are expected to conduct the investigation on top of their baseline activity. This inevitably creates a peak in workload and, along with the time constraints imposed on investigations, the quality of the investigation can consequently suffer.

107 There are three levels of investigation within Network Rail, depending on the severity of the incident: level 1 (preliminary), level 2 (local) or level 3 (formal). Level 1 investigations are completed within one week of the incident, and essentially act as a filter to determine whether the investigation needs to be escalated. Despite Network Rail's assertion that safety investigations should be separate from the disciplinary process, there is some evidence to suggest that those conducting level 1 investigations considered the investigation as being overshadowed by potential disciplinary action for the individual concerned.

108 Consequently, level 1 investigations tend to go no further than identifying causes associated with the individual involved (in these cases, the signaller). Any analysis of deeper, systemic causal factors would be reserved for a level 2 or level 3 investigation.

109 Nevertheless, of the 19 industry reports reviewed for the present investigation (which were a mix of levels 1, 2 and 3), 15 classified the behavioural cause as a 'slip/lapse' (a type of error) by the signaller. In RAIB investigations, individual actions are considered as the starting point for an examination of systemic causal and underlying factors that can influence all individuals on the front line.

110 The classification of behavioural cause follows Network Rail's 'fair culture' flowchart, which classifies the individual action to determine whether it was a reckless contravention, a slip/lapse, a mistake caused by the system, poor judgement, or a routine error. Some LOMs felt that the flowchart was too restrictive, forcing them into identifying an individual cause when the evidence pointed towards more systemic factors. From this perspective, it is unsurprising that most reports identified a behavioural cause of 'slip/lapse'.

111 As a consequence of identifying causes relating to individuals, many of the remedial outcomes also focused on individual signallers. In all of the industry reports reviewed for this investigation, the actions and recommendations included some level of retraining, monitoring or development for the signaller (although in eight cases, recommendations were also made to address systemic factors such as equipment design, competence management, or resourcing). Several of these involved actions to address non-technical skills, despite the difficulties that LOMs face in developing NTS (paragraph 92).

112 Of the 19 industry investigation reports reviewed for this class investigation, five specifically identified the development of signaller NTS as a recommendation or action. However, in only one of these (the incident at Heaton Norris; paragraph 25) did RAIB classify 'competence management' as a factor. Since NTS is aligned with competence management in the rail industry's framework, this supports the observation that industry investigators are resorting to NTS as a readily available solution when it is not necessarily appropriate.

113 Network Rail regards its options for addressing causal factors in the short-term to be limited to individual development or changes to rules and procedures. Wider, systemic changes are more complex, slow to implement, and necessarily expensive, so often wait until other major upgrades are taking place in order to be viable.

114 On a wider level, the analysis of trends across investigations is variable across Network Rail, but generally limited. Network Rail told RAIB that trend analysis is constrained by the data fields in the SMIS[15] incident database maintained by RSSB.[16] However, much of the potentially useful information in SMIS is handled in free text fields, which are difficult to search.

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[15] https://www.rssb.co.uk/en/Standards-and-Safety/Tools--Resources/Safety-Reporting-and-Intelligence-Systems/SMIS.

[16] A not-for-profit body whose members are the companies making up the railway industry. The company is registered as Rail Safety and Standards Board Ltd, but trades as RSSB.

Summary of conclusions

Causal factors

115 The common causal factors identified in this class investigation were:

a. Network Rail's management of signaller workload does not fully reflect the complex cognitive demands of modern signalling centres (paragraph 75, see paragraph 141 and **Recommendation 1**).

b. Network Rail's management of change does not consistently involve signallers in decisions about equipment or processes that affect their work (paragraph 81, **Recommendation 2**).

c. There are shortcomings in Network Rail's competence management arrangements for signallers (paragraph 87, see paragraphs 129 and 139, and **Recommendations 3 and 5**).

d. Network Rail's procedures and training for operating railway signalling do not sufficiently account for the information, strategies and knowledge used by experienced signallers (paragraph 95, **Recommendation 4**).

e. Local management structures within Network Rail adversely affect the competence management and professional development of signallers (paragraph 100, see paragraph 139 and **Recommendation 5**).

Additional observation

116 Although not a direct causal factor in signaller decision-making, RAIB observes that Network Rail's incident investigations do not always fully identify or exploit the opportunities to learn from those incidents (paragraph 105, see paragraph 142d, **Recommendation 6 and Learning point 1**).

Previous RAIB recommendations relevant to this investigation

117 The following recommendations, which were made by RAIB as a result of its previous investigations, have relevance to this investigation.

Fatal accident at Moreton-on-Lugg, near Hereford, 16 January 2010, RAIB report 04/2011, Recommendation 2

118 This recommendation read as follows:

> *Network Rail should enhance its level crossing risk management process to include identification, assessment and management of the risk associated with:*
>
> - *human error by signallers and crossing keepers;*
> - *operational arrangements, in particular with regard to the ability of operators to cope with interruptions, such as telephone calls, and other out-of-course events;*
> - *equipment design, in particular where it is not compliant with latest design standards; and*
> - *maintenance and inspection arrangements, particularly where these are used to identify and remedy any equipment functional and performance deficiency.*
>
> *The process should allow for sufficient liaison between the relevant engineering and operational departments.*
>
> *When addressing risks identified by the implementation of the revised process, Network Rail should prioritise the implementation of required mitigation measures to level crossings where consequences of operator error are severe and not protected by engineered safeguards.*

119 Although specific to level crossings, this recommendation has relevance to the current class investigation as it addresses signaller errors where there are no other engineered safeguards. Other parts of the recommendation also relate to signaller workload and equipment design, both factors in the current investigation (paragraphs 75 and 81 respectively).

120 In response to the recommendation, Network Rail carried out work to identify safety-critical errors associated with signallers and crossing keepers, which were incorporated into competency and risk assessment processes. ORR was initially satisfied with this response, but subsequently reported that the risk assessment process did not capture equipment design, and so the recommendation status reverted to ‘in progress’, which it remains at the time of writing this report.

121 Following the accident at Moreton-on-Lugg, Network Rail introduced Level Crossing Managers, a dedicated role to carry out inspections, risk assessments and maintenance on level crossings throughout a geographical area. These risk assessments take account of several factors associated with the crossing itself (including level of road and rail traffic, and specific local features). However, evidence collected in the current investigation suggested that factors associated with the signaller (such as workload or the availability of crossing information) do not feature in the risk assessments by level crossing managers (see also Recommendation 1 of RAIB report 11/2019).

Collision at Sewage Works Lane user worked crossing, near Sudbury, Suffolk, 17 August 2010, RAIB report 14/2011, Recommendation 2

122 This recommendation read as follows:

> *Network Rail should consider ways of managing the risk at user worked crossings equipped with telephones where long waiting times can arise as a result of the signaller having no means of knowing where trains are located, and implement any reasonably practicable measures identified.*

123 One of the outcomes of this recommendation was Network Rail's installation of a unique Train Advanced Warning System (TAWS) on the Witham workstation (which controls the Sudbury branch line) at Liverpool Street SCC. This additional screen displays satellite-based train location and direction, along with colour-coded guidance about the availability of UWCs according to the train's approach (figure 12), providing more information than the standard signalling interfaces. According to staff at Liverpool Street SCC, TAWS has been a successful and useful addition to the workstation. However, Network Rail told RAIB that the system has not been more widely implemented across the network as its technology is only suitable in specific circumstances.

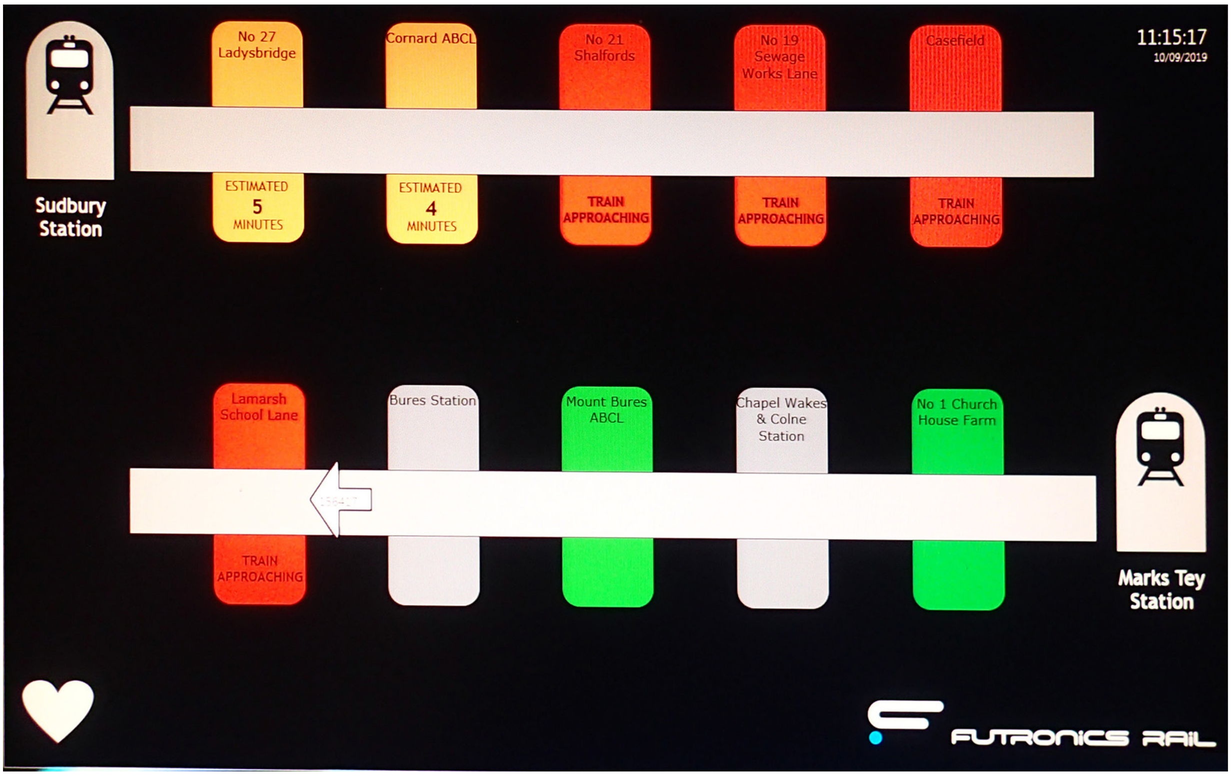

Figure 12: Image of the TAWS interface at Liverpool Street SCC, Witham workstation

124 Network Rail also committed to explore a range of other technological solutions to address recommendation 2 of the Sewage Works Lane report, some of which are still progressing (see paragraph 142a). Consequently, the current status of this recommendation as reported by ORR is 'in progress'.

Near miss incident at Ufton Automatic Half Barrier Crossing, Berkshire, 4 September 2011, RAIB report 28/2012, Recommendation 4

125 This recommendation read as follows:

> *Network Rail should examine and implement ways in which the workload of signallers can be kept within reasonable levels during engineering possessions, particularly those involving multiple changes to possession limits. This work should aim to avoid, where practical, situations in which signallers must delay engineering work or train services in order to avoid excessive workload.*

126 The incident at Ufton involved a level crossing on local control, and several other recommendations in RAIB's report addressed issues of information presentation on workstation-based signalling interfaces to support signaller decision-making. However, recommendation 4 directly addresses the factor of workload that was identified in this class investigation.

127 Although the recommendation addressed engineering possessions, Network Rail's response extended this to cover line blockages, offering a line blockage tool to identify and recommend limitations on the workload of signallers. However, according to the most recent response on this recommendation (dated 13 October 2014), the process needed more development, so ORR currently reports the status of this recommendation as 'in progress'.

128 Network Rail's current approach to managing signaller workload associated with line blockages is to place limits on the number of simultaneous line blockages per signaller (paragraph 47).

Derailment at Knaresborough, 7 November 2015, RAIB report 16/2016, Recommendation 1

129 This recommendation read as follows:

> *When carrying out its review of the effectiveness of the recently revised procedure 4-20 of the Operations Manual NR/L3/OPS/041, Network Rail should review whether the changes to the requirements on non-signallers have resulted in them maintaining the required level of knowledge and experience needed to operate the signalling locations for which they are authorised, including where it has not been practicable for them to operate those locations, and implement any further necessary changes.*

130 This recommendation relates to the factor associated with competence management in the present investigation: specifically, the issue of LOMs maintaining their own operational competence to work signalling locations at short notice (paragraph 93). Recommendation 3 in the current report addresses the factor of competence management, but does not include LOM operational competence since this is already covered in the Knaresborough recommendation.

131 In accordance with the recommendation, Network Rail reviewed its operations manual and updated it with a number of changes around the management of non-signaller competency. As a result, ORR has closed this recommendation as implemented.

Collision at Hockham Road user worked crossing, near Thetford, 10 April 2016, RAIB report 04/2017, Recommendation 1

132 This recommendation read as follows:

> *Network Rail should undertake a review of its measures for the protection of user worked crossings with the objective of identifying means of reducing the likelihood that an accident will be caused by signaller error. Options for consideration should include:*
>
> - *improved information for signallers (including consideration of ways of better enabling signallers to judge the time needed for a movement over a crossing and the time available before a train arrives at a level crossing);*
> - *ncreased use of automatic warning systems; and*
> - *closure of UWCs or their replacement by automatic crossings.*
>
> *The review should also identify criteria for the prioritisation of improvements taking into account both risk and the opportunities presented by planned signalling upgrades. The findings of the review should be incorporated into Network Rail's level crossing strategy and the standards used to prepare specifications for new signalling schemes.*

133 The relevance of this recommendation is associated with its call to reduce the likelihood of signaller error, albeit specifically at UWCs.

134 In response, Network Rail developed an action plan to develop potential solutions associated with signallers' decision-making and errors. While this is the aspect of most relevance to the present investigation, ORR noted that the response did not address the other two aspects of the recommendation. ORR is currently awaiting further information from Network Rail before deciding on the status of this recommendation.

Near miss at Dock Lane level crossing, Melton, Suffolk, 14 June 2016, RAIB report 08/2017, Recommendation 1

135 This recommendation read as follows:

> *Network Rail should review, and revise as necessary, its risk management processes so that the risk of signallers making errors when controlling telephone operated level crossings is taken into account when identifying appropriate improvement options. This should include consideration of factors that affect:*
>
> - *the probability of signallers making errors; and*
> - *the number of crossing decisions that signallers are required to make.*
>
> *Network Rail should also clearly identify who is responsible for assessing the risk associated with signallers making such errors.*

136 A key concern at Dock Lane was the cumulative effect on signaller workload of incremental changes to the task (namely, the addition of telephones to several user worked crossings). While this recommendation is specific to telephone operated level crossings, its relevance to the present investigation is nonetheless clear in respect of signaller error risk management. It also potentially addresses the issue of Level Crossing Managers accounting for factors affecting the signaller in their risk assessments (paragraph 121).

137 At the time of writing, ORR has not notified RAIB of a formal response to this recommendation from Network Rail. However, Network Rail told RAIB that, as a result of this recommendation, it implemented a new national operating procedure[17] in June 2019 for LOMs to conduct regular operational workload assessments at each signalling location.

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[17] NR/L3/OPS/045/3.37 Network Rail National Operating Procedure 3.37 Operational Workload Assessment, Issue 1, 1 June 2019.

Industry actions

Actions either undertaken or planned by Network Rail

138 In 2003, Network Rail commissioned research[18] to understand signaller errors, with a similar remit to this class investigation. Figure 13 summarises the findings of that research; with the exception of 'signal put back inappropriately', the remaining error types reflect similar factors and categories of incident as in this investigation (albeit divided differently). One key finding was that most of these errors were made by inexperienced or trainee signallers. The report made several recommendations in areas including training, information requirements for signallers, and human factors integration in system design. Network Rail told RAIB that the organisation and its operations have changed considerably since 2003, and some (though not all) of the recommendations from this report have been addressed through other initiatives.

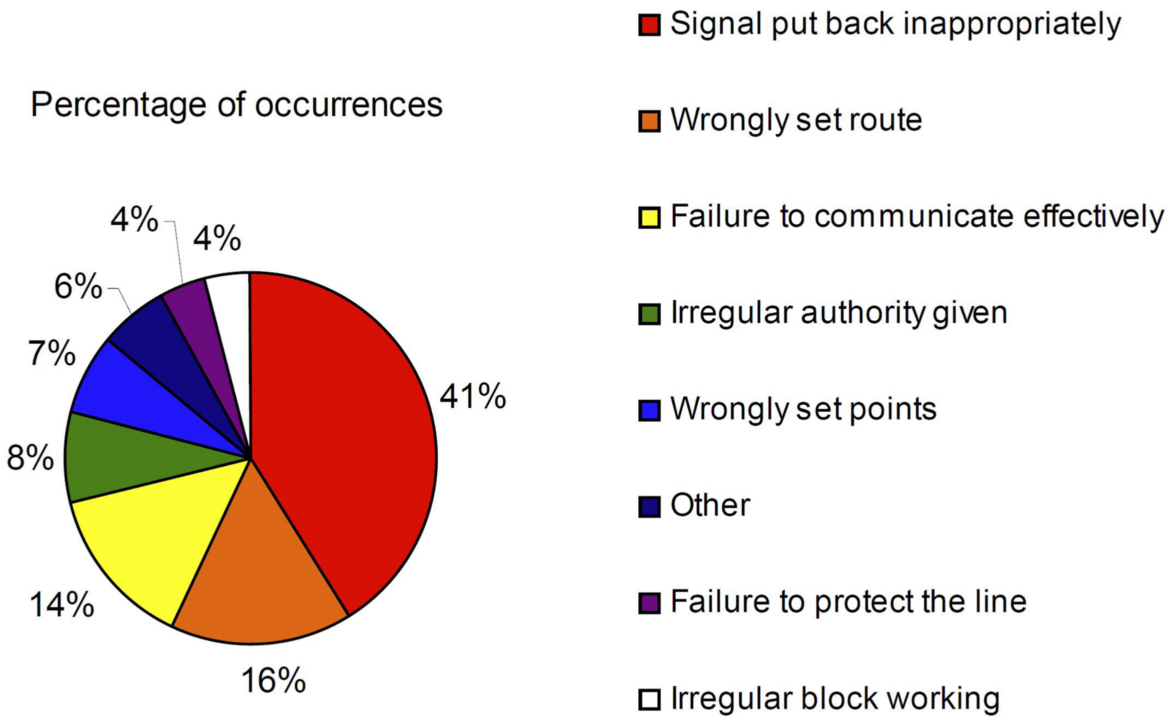

Figure 13: Proportion and types of signaller error identified in Network Rail's 2003 research report (courtesy Network Rail)

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[18] 'An investigation into signaller error', report 5502 by Laura Sutton Associates for Network Rail, June 2003.

139 In late 2018, Network Rail began working on a National Operations Programme, which has continued throughout the course of this class investigation. Although independent from this investigation, the programme has a similar motivation as it was instigated in response to an increase in significant incidents caused by signallers from 2014 to 2018. It has so far identified, and has set out a series of objectives to address, many similar findings as this investigation, such as the issues with competence management, workload and resourcing (including, notably, making decisions about centralised signalling control centres based on signaller capability rather than business strategy), difficulties in dealing with non-technical skills, and organisational factors associated with the LOM role. As such, it supports both the rationale for conducting this class investigation as well as its conclusions.

140 In December 2019, Network Rail issued a new national operating procedure[19] for operational competence management, which details the training and development activities for operational managers (including LOMs). As well as specifying the operational competence required of managers, this document also sets out requirements for people management, skills assessor training, and the assessment and development of non-technical skills.

141 Regarding signaller workload, Network Rail told RAIB that it has a long term aim to develop a workload modelling approach that will take better account of tacit, cognitive demand. In the meantime, Network Rail plans to gather subjective workload data to support front-line operations managers in determining workload capacity for dealing with line blockage requests.

142 Network Rail also reported to RAIB a range of activities either planned or underway that are relevant to this investigation, including:

a. trials of a process to help signallers determine decision points for UWCs in areas with long signal sections, with funding over the next five years to develop technology to support such decisions

b. investigating visualisation tools to better engage signalling staff with the design process

c. sponsoring a cross-industry RSSB research project (T1171, 'Evaluation of Human Performance of Train Drivers, Signallers and Track Staff') which includes the aim of understanding signaller performance

d. a review of the fair culture process for investigations and the implementation of dedicated and independent investigation manager posts in each route.

Actions by other parties

143 The ISLG conducted its own study of track worker safety in line blockages and possessions in 2018. Although concerned with track worker safety in general, this work encompassed risks arising from actions by the signaller. The ISLG's findings have already been touched upon earlier in this report (paragraph 44).

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[19] NR/L3/OPS/045/2.04 Network Rail National Operating Procedure 2.04 Operational Competence Management, Issue 1, 7 December 2019.

144 Figure 14 summarises some of the more detailed findings which again reflect the scenarios covered in the present investigation. Relevant recommendations from the ISLG report include improvements to the forms that signallers use for line blockages, training, organisational structures, and signaller workload. Network Rail advised RAIB that many of these issues are being addressed in other initiatives associated with track worker safety.

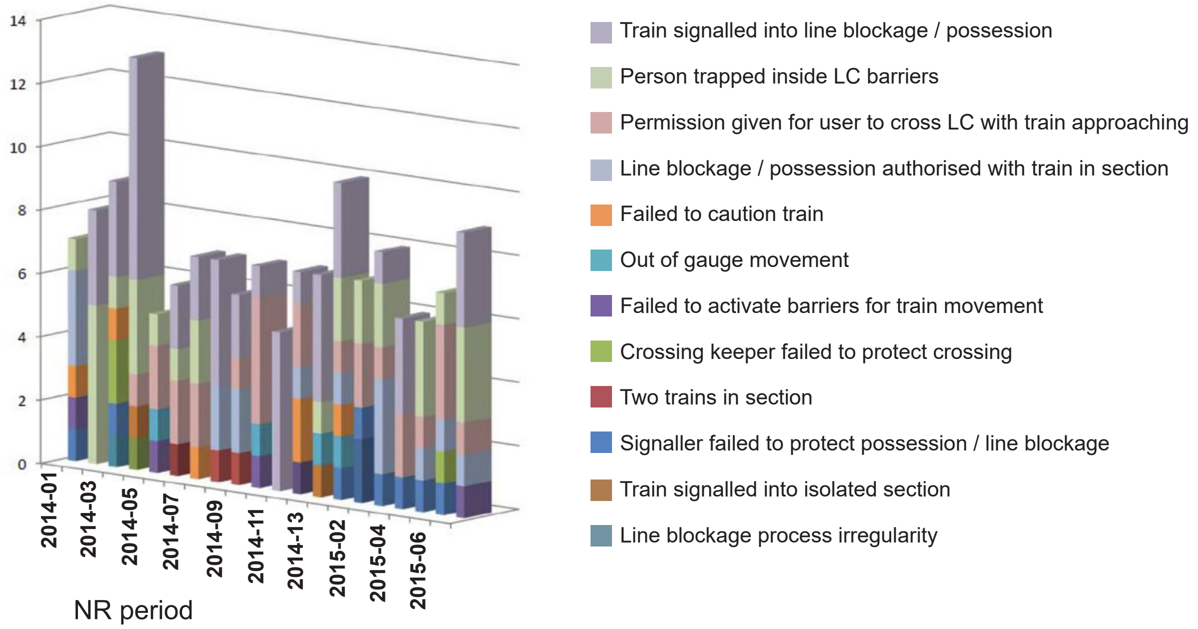

Figure 14: Industry data on operational incidents (courtesy ISLG). Note that with the exceptions of 'failed to caution train', 'out of gauge movement', and 'train signalled into isolated section', all of the other categories have parallels with the scenarios covered in the present investigation.

145 In 2018, ORR conducted inspections of signaller performance and error management across four of Network Rail's routes (Anglia, Scotland, South East and Wessex). As with Network Rail's National Operations Programme, these inspections were in response to an increase in operational irregularities made by signallers in 2016-17. On the whole, ORR found that the existing procedural safeguards in place to control the risk arising from signaller critical errors (including, principally, competence management) were largely effective and were being followed. Nevertheless, the ORR reports also presented supporting evidence for many of the factors identified in this investigation, such as signaller workload, experiential knowledge, equipment design, local management, and industry investigations.

146 On 30 March 2017, ORR also served an Improvement Notice on Network Rail's Anglia route regarding the risk to signallers' decisions at UWCs from long signal sections and signaller workload. Initially, ORR required Network Rail to identify and assess the risk. In response, Network Rail carried out extensive work and prepared a list of improvement actions, including an ergonomics assessment checklist to enable the identification of factors affecting signallers. ORR welcomed these proposals and so subsequently issued a further Improvement Notice on 23 January 2018 to ensure that Network Rail carries out these actions by 31 March 2021. Network Rail's actions referred to earlier (paragraph 142a) are part of its response to the Improvement Notice.

147 RSSB reported new functionality within SMIS to capture and classify incident causes. This functionality is being rolled out across the rail industry, with some companies already using it.

Recommendations and learning point

Recommendations

148 The following recommendations are made:[20]

1 *The intent of this recommendation is to reduce the risks associated with excessive signaller workload through better understanding of mental workload, reflecting the fact that contemporary signalling increasingly imposes demands on the thought processes of signallers that are unobservable and hence not easily captured by existing metrics.*

Network Rail should develop improved techniques for measuring and predicting cognitive aspects of signaller workload, building on the existing research it has conducted in this area, and integrate the use of such techniques in its management of signaller workload (paragraph 115a).

2 *The intent of this recommendation is to optimise the working environment of signallers by ensuring that any changes impacting on their tasks, processes or equipment, take account of their views and experience, through involving them in the change management process.*

Network Rail should review its processes for incorporating a user-centred approach into any changes that have the potential to affect signallers' work. This review should include Network Rail's standard relating to ergonomic design, to determine whether its scope is appropriately defined, and whether it is being properly complied with. Network Rail should then implement any necessary changes to address the relevant factor in this investigation (paragraph 115b).

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[20] Those identified in the recommendations have a general and ongoing obligation to comply with health and safety legislation, and need to take these recommendations into account in ensuring the safety of their employees and others.

Additionally, for the purposes of regulation 12(1) of the Railways (Accident Investigation and Reporting) Regulations 2005, these recommendations are addressed to the Office of Rail and Road to enable it to carry out its duties under regulation 12(2) to:

(a) ensure that recommendations are duly considered and where appropriate acted upon; and

(b) report back to RAIB details of any implementation measures, or the reasons why no implementation measures are being taken.

Copies of both the regulations and the accompanying guidance notes (paragraphs 200 to 203) can be found on RAIB's website www.gov.uk/raib.

3 *The intent of this recommendation is to improve signaller performance and reduce the occurrence of incidents by addressing shortcomings in the competence management of signallers.*

Network Rail should provide development and support for all those involved in delivering training and assessment of signallers at local level to ensure that they are suitably qualified, experienced and resourced to do so. This should include, but not be limited to, providing additional ‘train-the-trainer’ guidance in coaching for relevant non-technical skills as well as encouraging the use of simulators as tools to develop signallers’ capabilities (paragraph 115c).

4 *The intent of this recommendation is to improve the capabilities of all signallers through training that better understands the information, strategies and knowledge used by experienced signallers.*

Network Rail should carry out research with the objective of better understanding what constitutes experiential knowledge of experienced signallers (both in general and specific to a location), how such knowledge contributes to safe and efficient performance, and then incorporating the findings into the training and development of all signallers (paragraph 115d). This may include, but not be limited to, training at signalling school and/or local initiatives, such as structured mentoring, simulated scenarios or operational exercises for both initial and refresher training.

5 *The intent of this recommendation is to improve the supervision, monitoring and competence management of signallers by addressing the organisational factors associated with the current line management arrangements.*

Network Rail should implement measures in its National Operations Programme aimed at revising management arrangements to ensure that those with the responsibility for supervising and managing signallers (such as Shift Managers and Local Operations Managers) have the time, people skills, knowledge and status that are needed to undertake their role effectively (paragraphs 115c and 115e). These arrangements should include the capacity, capability and organisational structure to facilitate competence management as well as the personal, professional and career development of signallers.

6 *The intent of this recommendation is to improve Network Rail's learning from operational incidents.*

Network Rail should review and, as appropriate, modify or reinforce its processes for investigating incidents in the following areas (paragraph 116):

- appropriate use of the 'fair culture' flowchart and subsequent analysis of underlying factors (such as use of the 10 incident factors from RIS-3119-TOM) to ensure the causes of incidents are appropriately categorised
- wider trend analysis across all levels of investigation to identify deeper systemic issues
- achieving full separation of safety investigations from the disciplinary process.

Learning point

149 RAIB has identified the following important learning point:[21]

1 Incident investigators should consider the potential for multiple, interacting factors involved at all levels of the system, regardless of the level of the investigation concerned. Focussing the analysis and recommendations on immediate human errors and the non-technical skills of individuals involved, or fitting factors to predefined classifications, could result in vital learning being overlooked. Although RAIB recognises the value in classification schemes, as well as the fact that it is not always practicable to make recommendations at a systemic level, the fundamental factors should still be identified and described to support wider learning from incidents.

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[21] 'Learning points' are intended to disseminate safety learning that is not covered by a recommendation. They are included in a report when RAIB wishes to reinforce the importance of compliance with existing safety arrangements (where RAIB has not identified management issues that justify a recommendation) and the consequences of failing to do so. They also record good practice and actions already taken by industry bodies that may have a wider application.

Appendices

Appendix A - Glossary of abbreviations and acronyms

ARS	Automatic Route Setting
CCTV	Closed Circuit Television
ISLG	Infrastructure Safety Leadership Group
LOM	Local Operations Manager
NTS	Non-Technical Skills
ORR	Office of Rail and Road
SCC	Signalling Control Centre
SMIS	Safety Management Intelligence System
TAWS	Train Advanced Warning System
UWC	User Worked Crossing

Appendix B - Investigation details

The objectives of RAIB's investigation were to:

- establish the nature of the task(s) in question and the extent of the concerns under investigation
- here appropriate, draw comparisons between operations on the national network and those of other UK railways
- understand common factors influencing the actions of the people involved, under both normal and out-of-course conditions
- review the arrangements for managing risk for each of those factors
- consider the impact of recent and ongoing developments in working arrangements (such as more centralised network control)
- explore any further underlying organisational or external factors
- make recommendations, at a systems level, to improve safety.

RAIB used the following sources of evidence in this investigation:

- observations of, and group interviews with, signallers at four signalling locations
- data collected from Network Rail's national incident logs
- industry investigation reports
- Network Rail procedures and standards relating to signaller training and competence management
- industry standards relating to signalling operations
- an expert report from Newcastle University commissioned by RAIB
- a review of research papers and industry reports relevant to this investigation (Appendix C)
- a review of previous RAIB investigations that had relevance to this class investigation (Appendix D).

Appendix C - Bibliography

The following appendix lists key research papers and industry reports that RAIB referred to for this investigation:

Research papers

Golightly, D., Ryan, B. & Sharples, S. (2010). ‘Cognitive Work Analysis of signalling protection for rail engineering’. In M. Anderson (Ed.), Contemporary Ergonomics and Human Factors 2010 (pp 412-420). Taylor & Francis

Pickup, L., Balfe, N., Lowe, E. & Wilson, J.R. (2013). ‘”He’s not from around here!” The significance of local knowledge.’ In N. Dadashi, A. Scott, J.R. Wilson & A. Mills (Eds), Rail Human Factors: Supporting reliability, safety and cost reduction (pp. 357-366). Boca Raton, FL: CRC Press

Hack, C. & Carey, M. (2017). ‘Reducing the risk of signallers giving level crossing users permission to cross when it is not safe to do so’. Paper presented at the Sixth International Human Factors Rail Conference

Industry reports

‘An investigation into signaller error’, report 5502 by Laura Sutton Associates for Network Rail, June 2003

‘Human factors study of railway worker information requirements – User Information Requirements Study’, RSSB T149 report prepared by Qinetiq (QINETIQ/KI/CHS/CR032510/2.0), Issue 2.0, 5 Jan 2004

‘Railway Action Reliability Assessment user manual: A technique for the quantification of human error in the rail industry’, final deliverable for RSSB project T270, June 2012

‘HF Analysis of failure modes resulting in trains incorrectly entering Line Blockages and Possessions’, ISLG report no. ISLG-01-R-01, Issue 1.0, 23 May 2017 (prepared by Risktec Solutions Limited)

‘Track Worker Safety in Line Blockages and Possessions: Summary Report and Conclusions’, Issue 1, 4 May 2018. Infrastructure Safety Leadership Group

‘Signaller Performance Wessex Route 2017/18’, ORR report NRIP Topic INS-0958, March 2018

‘Signallers Intervention: Anglia Route’, ORR report March 2018

‘NRIP Signaller Error Risk Management in Scotland Route Inspection 2017/18’, ORR report March 2018

‘Signaller Performance Remit South East Route 2017/18’, ORR report NRIP INS-0958, October 2018

Appendix D - List of relevant previous RAIB investigation reports

The following appendix lists RAIB investigation reports used in this class investigation, categorised according to incident type (* denotes a bulletin or safety digest as opposed to a full investigation report).

User worked crossing irregularities

- Collision between a train and a tractor, White House Farm User Worked Crossing, 25 September 2011 (RAIB report 06/2012)
- Dangerous occurrence at Lindridge Farm user worked crossing, near Bagworth, Leicestershire, 22 March 2012 (RAIB report 11/2013)
- *Near miss at Four Lane Ends level crossing, near Burscough Bridge, Lancashire, 28 September 2012 (RAIB bulletin 01/2013)
- Collision between a train and a tractor at Hockham Road user worked crossing, near Thetford, 10 April 2016 (RAIB report 04/2017)
- Near miss between a train and a level crossing user at Dock Lane, Melton, Suffolk, 14 June 2016 (RAIB report 08/2017)
- *Near miss at Thorney Marsh Lane level crossing, Castle Cary, Somerset, 26 November 2016 (RAIB safety digest 02/2017)
- Fatal accident at Trenos footpath crossing near Llanharan, Rhondda Cynon Taf, South Wales, 1 June 2017 (RAIB report 07/2018)
- *Near miss at Plain Moor user worked crossing, Barton-le-Willows, North Yorkshire, 7 July 2018 (RAIB safety digest 09/2018)
- Serious operational irregularity at Bagillt user worked crossing, Flintshire, involving an abnormally heavy road vehicle, 17 August 2018 (RAIB report 11/2019).

Line blockage irregularities

- Track worker near miss incidents at Camden Junction South, London, 28 February 2017 (RAIB report 16/2017).

Irregularities involving level crossings on local control

- Train passed over Lydney level crossing with crossing barriers raised, 23 March 2011 (RAIB report 20/2011)
- Near miss at Ufton Automatic Half Barrier Crossing, Berkshire, 4 September 2011 (RAIB report 28/2012)
- *Dangerous occurrence at Broad Oak level crossing near Canterbury, Kent, 29 June 2017 (RAIB safety digest 13/2017)
- *Near miss at Magdalen Road level crossing, 9 August 2017 (RAIB safety digest 14/2017).

Operational irregularities

- Derailment of a freight train at Maltby North, 28 June 2006 (RAIB report 24/2007)
- *Freight train derailed in July 2008 (Doncaster, 23 July 2008) (RAIB bulletin 03/2008)

- Derailment of two locomotives at East Somerset Junction, 10 November 2008 (RAIB report 28/2009)
- *Passenger train derailed in November 2008 (Bognor Regis, 14 November 2008) (RAIB bulletin 04/2009)
- Derailment at Knaresborough, 7 November 2015 (RAIB report 16/2016)
- *Passenger train derailment at Penryn, 28 January 2019 (RAIB safety digest 03/2019).

Appendix E - Summary of field work

The following is a summary of the outputs from a Cognitive Task Analysis of rail signalling, carried out by Dr David Golightly of Newcastle University in support of the current class investigation.

Problem Statement

RAIB has investigated numerous incidents in which the decisions of front-line workers have been pivotal, and where the safety of the railway system has been entirely dependent on those decisions (that is, the decision of the front-line worker has been the last line of defence). Typical scenarios include:

1. user worked crossings
2. trappings at full barrier level crossings
3. line blockages
4. level crossings on local control
5. operational irregularities such as wrong routeing of trains.

Understanding the events, constraints and processes that shape human decision-making in these scenarios, and across signalling generally, can identify potential common causal factors that might lead to incidents and point to subsequent recommendations. To that end, a Cognitive Task Analysis (CTA) was conducted with signallers. This technique highlights the aspects of cognition used in work (perception, memory, knowledge, decision-making) and the factors that shape cognitive performance, and may equally draw attention to those aspects of the work (technical, procedural and organisational) that shape cognitive performance. The CTA was informed by an approach known as naturalistic decision-making, which considers expert decision-making as being rooted in contextual factors built on practice and experience. This reflects signaller decisions that are based not only on an understanding of the rules, but also on extended experience with a given workstation, area of control, local geographical factors and different types of events and operational situations.

Data collection and analysis

The CTA was based on data generated through two means:

1. observations of seven different signallers in four locations representing three types of signalling environment (lever frame, panel, workstation), supplemented with informal commentary (where practicable) from the seven signallers
2. group interviews with a total of nine signallers and, in order to understand broader operational factors, interviews with a total of six Local Operations Managers and one Operations Manager.

The interviews were analysed thematically with all the data then being structured using:

1. indicative quantitative outputs from the observations
2. a tabulated decision-making analysis based on the scenarios identified and performance influencing factors
3. a narrative on additional themes emerging from the interviews.

This dataset was then fed through a suite of cognitive analysis tools to produce a model of signalling performance that captured elements of the cognitive work that is involved in signalling.

Results and conclusions

In terms of decision-making, signallers use a combination of strategy, informal cues and knowledge of local conditions to make their decisions. This reflects a complex array of local operational factors (in terms of the traffic, technology, infrastructure and local geography) that has a profound effect on both individual signaller strategy and local implementation of rules, resulting in variety in how some processes are applied. Strategies and knowledge are learned locally and shared between signallers, but are also based on the extended experience of signallers. Decisions are generally made to ensure safety while maintaining performance as much as possible, though signallers feel a clear pressure or conflict between these. The need to manage the general public at user worked crossings and other types of level crossing is an additional factor in decision-making.

Specific factors existed for user worked crossings (including lack of information on train position, variability in behaviour of users at crossings), CCTV (such as poor quality cameras or monitors), and line blockages (for example, timing of requests, fitting in around the train service, quality of communications and planning). Signallers and managers believed these three types of scenario posed the greatest ongoing safety risk. While there was less specific discussion of operational irregularities, automation was raised as a concern. There was little explicit data on local control of level crossings, and no other types of issues were raised voluntarily.

However, the major factor from the scenarios was not the individual scenarios but how they interact when occurring concurrently on a workstation. Workload from one issue or scenario can distract from other tasks on the workstation (for instance, setting up a line blockage can lead to an operational irregularity because the signaller fails to notice routes set by automatic route setting). A combination of minor events could be just as demanding, albeit for a shorter time, as more significant events. The ability to multi-task is therefore vital to performance. Ultimately, this is a question of workload and workload management, which is often exacerbated by limited resource in the box and rostering arrangements which are not ideal. Teamwork, and licence to push back on requests such as line blockages at times of high workload, were seen as critical to maintaining safety.

All of these are represented in the outputs of the cognitive modelling. In particular, the models demonstrated the key role of signaller awareness of workstation status in underpinning all other functions, yet this function is covert and susceptible to workload factors, including those from other functions. Consequently, degradation in this awareness typically emerges as slips or lapses in other functions.

The analyses also highlighted the competing demands on signallers, with some (such as managing the public) not having been recognised in previous studies. A significant decision point for the signaller is in accurately ascertaining the window of opportunity for functions based on their requirements (such as the length of a line blockage or a request at a user worked crossing). Finally, the model also revealed the systemic, interconnected nature of signaller tasks. Signaller work is hugely influenced by performance criteria and there are examples across the analysis of signallers working within a trade-off of efficiency while maintaining safety (thoroughness).

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